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REVIEWS

The Geology of the Lake Superior Region. By CHARLES RICHARD VAN HISE and CHARLES KENNETH LEITH. United States Geological Survey, Monograph LII. Pp. 641; Figs. 76; Pls. 49.

All geologists interested in pre-Cambrian geology will view with pleasure the appearance of this monograph. While the work is to a considerable extent a compilation of all other important publications on this region it contains much which is new and a great deal of information, especially on the origin of the iron ores, which here appears in print for the first time. The geography, general geology, bibliography, and history of the economic development of the region are discussed in a general way. These discussions are followed by detailed descriptions of the geology of the various ore-bearing districts, the geological series, the glacial geology, the origin of the ores of iron and copper, a genetic classification of the iron ores of the world, and finally by a summary of the geological history of the region with special mention of the unconformities separating the different series.

The region covers an area of approximately 181,000 square miles of which the copper and the ten great iron-bearing districts combined make less than 3 per cent of the total. The relief varies from a maximum elevation of 2,230 feet above sea-level in Minnesota to a minimum of 376 feet below sea-level in the basin of Lake Superior.

In the section on physical geography, edited by Lawrence Martin, it is concluded from a discussion of the peneplaination of the area that the region was base-leveled in pre-Cambrian time. While the subject is treated from nearly all standpoints and the matter presented is good the reader feels that although such a statement as, "Earlier possible peneplain levels—in the Huronian for example—would have been warped or folded by pre-Algonkian deformation," appearing on p. 88, must be assigned to an oversight or a typographical error, great difficulty is experienced in distinguishing between statements which refer to the present peneplain and those which refer to the plain which was doubtless formed in the early Algonkian. Observations are made regarding the origin of the Lake Superior basin and the conclusion reached that it is largely due to graben faulting and glacial erosion.

Much new data relating to the iron ores has been collected, especially regarding their chemical composition, porosity, and moisture content, and the results have been depicted graphically on the triangular diagram which is so frequently employed in this work. It is shown that the phosphorous in the ore of the Mesabi district has come chiefly from the overlying Cretaceous rocks while in the Penokee-Gogebic district the phosphorous content of the ore increases with the percentage of iron indicating that this element was originally in the ore. In the vicinity of dikes the phosphorous content is high and leached dikes show a loss of this element so the igneous rocks appear to be the original source of it. No definite phosphorous minerals have been found, but the association of calcium and phosphorous in some of the deposits suggests the presence of apatite.

The average analysis of ore from the Mesabi district for three years shows a decrease from 60.70 per cent to 58.83 per cent in iron and a corresponding increase in phosphorous.

In the description of the Marquette district, peridotite as well as syenite is considered of Laurentian age and this fact is of interest since we have become so accustomed to thinking of this series as acid in composition. Regarding the placing of slates under the Ely Greenstone, as is done on p. 119, the question might be raised, whether it would not be better to reserve the term greenstone for lithological characters and apply it only to chemically and mineralogically altered, basic, igneous rocks.

The Keweenawan series is regarded as largely terrestrial in origin and a number of excellent reasons are given for drawing this conclusion. A few of these are: the thickness of the sediments and the frequent repetition of conglomerate beds; the feldspathic, poorly assorted and almost completely oxidized character of the sediments; the frequent occurrence of ripple-marks and mud-cracks, and the fact that the matrix of the basal conglomerate on the north shore is frequently limestone in such a condition as to suggest subaerial deposition similar to that occurring in the Bighorn Mountains at the present day.

The origin of the Keweenawan igneous rocks is assigned to fissure eruptions in the vicinity of the Lake Superior basin caused by orogenic movements and the down-warping of the basin apparently began in the Middle Keweenawan epoch. The source of the sediments is found chiefly in the underlying igneous rocks and the maximum thickness of the series is regarded as not more than half of that which was assigned to these rocks by some earlier writers. The discrepancy is due to the consideration that they were deposited on an inclined surface.

In the classification of the Keweenawan igneous rocks, p. 396, by A. N. Winchell, the term plagioclasite is used as a synonym for anorthosite. While this term is not so euphonious as anorthosite and might include rocks of greater range in chemical composition than that usually designated by this term it has simplicity and the advantage of corresponding in use to the terms amphibolite, pyroxenite, and leucitite.

The Lake Superior sandstone is for various reasons assigned to the Cambrian.

Beginning with chap. xvii the iron ores are discussed in great detail. The deposits are divided, chiefly on a genetic basis, into the pre-Cambrian sedimentary types, the source of nearly all the ore; titaniferous magnetites constituting magmatic segregations in gabbros; magnetic ores representing pegmatite intrusions in basic rocks; residual bog ores of Paleozoic age; and hematites from the Clinton series. The average iron content of all the original phases of the pre-Cambrian iron-bearing formations, not including the slates, is 24.8 per cent and the average for the ferruginous schists and jaspers is 26.33 per cent. If the average be taken for the formations including the ores the content of iron is 38 per cent showing the influence of concentration.

About $21,600,000 has been spent in diamond drilling in the region at an average cost of about $3. per foot. The average cost of mining underground is probably about $1. per ton, and the cost of transporting ore to the furnaces (in 1907) about $2.14 per ton. The stripping operations in the Mesabi district annually exceed in extent those on the Panama Canal.

The estimated reserves of pre-Cambrian ores is placed at 1,905,000,000 long tons.

The genesis of the sedimentary iron formations is the topic of greatest interest in this monograph and it is interesting to see the change of view by the senior author. He has to a large degree forsaken his earlier views which held that the iron deposits were principally the products of rock weathering for those which consider these deposits as coming chiefly either directly or indirectly from igneous rocks without the action of ordinary weathering agencies. The fact that anyone so familiar with these deposits as President Van Hise should adopt the new theory is a strong point in its favor. The hypothesis now accepted by the authors for the origin of the deposits is, briefly, that they are principally chemical sediments, that the original minerals were largely iron carbonate and silicate with some ferric oxides. The greater portion of the ore owes its present condition to secondary enrichment under special topographical and structural conditions although a smaller portion may have been laid down originally with practically the present content of iron. The materials forming the schist, iron carbonate, and silicate are supposed to have been derived principally from basic igneous rocks either as magmatic solutions poured into the sea or from solutions of iron salts in sea water formed by the action of hot igneous rocks coming in contact with the salt water. Some of the iron was derived from these basic rocks by weathering and transported to delta deposits while other portions were deposited in bogs and lagoons through the action of plant life as bog ore is deposited at the present time. This bog and lagoon origin is assigned to the lenses of carbonate in carbonaceous slates and shales which appear to be delta deposits but the conclusions of Weidman that the Baraboo and much of the Lake Superior deposits are of this origin are not accepted. A pegmatitic origin is suggested for a portion of the iron and silica and some good evidence is presented from the Vermilion district in support of this view. A great deal of evidence is also presented to show that the ellipsoidal character of the greenstones is due to extrusion under water but on account of conflicting evidence, which has been impartially presented, it is felt that the case has not been made definite. It is argued further from the results of a large amount of data collected that ordinary weathering conditions could not produce such great deposits of chemical sediments without more clastic materials because there is not sufficient iron in the surface rocks nor adequate agencies to transport the iron to the site of deposition. These arguments are supported by a set of laboratory experiments which show that the very conditions postulated for the field can be produced in the chemical laboratory.

In these experiments it was shown that if hot Keewatin basalt be sprayed with salt water, a water-glass glaze is formed and if this water-glass be neutralized by hydrochloric acid, silicic acid and sodium chloride are produced. If the solution then be boiled it becomes alkaline. Thus is demonstrated a source for the alkaline silicates and when ferrous chloride and sodium silicate react, iron silicate (greenalite) and sodium chloride are formed. If iron silicate be attacked by carbon dioxide there is produced iron carbonate and silica. Further, if silicic acid be boiled with iron carbonate, greenalite is formed. These and many other experiments demonstrate the possible source of the material for the building up of the greenalite, siderite, and cherty deposits. Of particular interest is the statement that the precipitates of these substances show a distinct tendency toward banding.

The theory of origin as outlined in this work is the most complete exposition of the subject yet presented and it would be unreasonable to doubt, in the presence of the facts presented, the probability of the origin of a great deal of iron by its direct extraction from the igneous rocks in the manner above stated. The description of the possible origin of the banding in the jaspers is without doubt the best solution of the problem yet offered, as this feature of the deposits has always been a very difficult one to explain by any other theory. However, while it is not the purpose of this review to offer a better theory for the origin of these deposits, it might be remarked that while the authors have been fair and impartial in the presentation of this theory, which is largely new but still embodying some of the principles of one of H. N. Winchell's earlier hypotheses, there are a number of arguments which will not be accepted by those who hold that the weathering of rocks is the most important feature in the development of these deposits. It may be felt that sufficient importance has not been attached to the influence of physiographic conditions during the weathering processes, because bog deposits are developed under special topographic conditions, and the fact that so little iron was deposited in the Lower Huronian might be explained by the fact that during the early part of the epoch the relief was great and coarse clastic sediment was being deposited rapidly at the expense of the finer chemical sediments. Could not the fact that the percentage of iron in the iron formation is so large, compared with the amount of the clastics, be explained by selective transportation by which the chemical sediments were carried to lower ground and the clastics left to a greater degree on the higher levels? In the folding which followed the lower would be folded down and preserved in the synclines. Nor is the possible source of iron in the Huronian by the destruction of Keewatin iron deposits given sufficient prominence, as the amount of these rocks destroyed must have been very great. While there is comparatively little clastic sediment in the Keewatin of the Vermilion range there is much feldspathic, poorly assorted material in many other areas of iron-formation, which the authors regard as Keewatin, and which are in all other respects very similar to the Vermilion area. As to the question why there is not much iron in the great sedimentary series of the Paleozoic, which have been produced under normal weathering conditions, it may be replied that there are large deposits, without associated igneous rocks, in the Clinton series and Pennsylvanian system, both of which followed a period of extensive deposition of clastics, which represented probably subaerial conditions and the destruction of great quantities of pre-Cambrian rocks. Although these deposits do not compare with those of the Huronian and Keewatin in extent, there never has been a period in the earth's history when such areas of fresh igneous rock in such a condition for rapid disintegration were exposed to weathering processes, nor have there been more favorable physiographic conditions for deposition than in Keewatin time. Regarding the relation of the iron-formation to different types of sediments it may be shown that the normal relation of bog deposits to clastic sediments today is that here they lie on sand and there on clay.

The origin of the copper ores of the Keweenawan is assigned chiefly to solutions of magmatic waters and to a lesser extent to the leaching of the igneous and sedimentary rocks by thermal waters. While this view is not entirely new it is much better established here than ever before by the application to the problem of rock alteration, the knowledge now possessed of the difference between the results of alteration by thermal solutions and by ordinary weathering processes. The presence of considerable chlorine in the deep-mine waters and the general scarcity of sulphides suggest that the chloride of copper was the principal compound in which the copper was originally transported. The copper was then brought to the metallic condition through the influence of ferrous compounds. The decreasing copper content of the deposits with depth is assigned to the nature of original deposition and not to secondary enrichment, as very little of the native copper is dissolved and transported.

The silver deposits on the north shore of Lake Superior are also regarded as having their origin in the Keweenawan, basic, intrusive rocks, and it is shown that chlorine is present to a marked extent in the deep-mine waters. From observations of certain similarities in geological characters it is therefore concluded that the Keweenawan copper, the Silver Islet silver, the Bruce Mines copper, the Sudbury nickel, and the Cobalt silver deposits are portions of a great metallographic province.

In a brief account of the Paleozoic rocks on p. 615, the term Proterozoic is introduced and made to include the Archean as well as the four members of the Algonkian group. This is not the sense in which the term has been used by other geologists and we surely have enough geological terms with two or more meanings. The author's use is a pointed illustration of the unsatisfactory usage which led to the adoption of the term Proterozoic, that is the illogical practice of including under a term of inferior rank the four great systems, Keweenawan, Upper Huronian (Animikie), Middle Huronian, and Lower Huronian, as well as the unknown deposits represented by the great unconformities that lie between these. The use of Proterozoic for these four systems as a group implies that taken together they are regarded as similar in importance to the Paleozoic, Mesozoic, and Cenozoic groups. To include the still greater Archean series, with its unknown extension downward, under the term Proterozoic is to introduce a usage more unfortunate than that which preceded the adoption of the term Proterozoic. The authors of this monograph have always stood for a sharp line of demarkation between the Archean and other rocks of the pre-Cambrian. It would have been easy to have said Proterozoic and Archean and thus to have given to the group included under the name Algonkian the dignity to which it is thought to be entitled by those who use the term Proterozoic for it.

In the account of the great unconformity between the Upper Huronian and underlying rocks, given on p. 619, those who have held that the term Animikie should be applied to this as a distinct system, separated from the Huronian, will find much to justify their views.

In conclusion I would state that this monograph, aside from a few points mentioned, is logically arranged and very clearly written and, considering the number, variety, and excellence of the illustrations and having regard for the amount of detailed work, the results of which are here given, it must be considered as one of the finest publications of the Geological Survey.

E. S. MOORE

"Versuche über Umkristallisation von Gesteinen im festen Zustande." VON F. LEEWINSON LESSING. *Centralblatt für Min., etc.*, No. 19, (October 1, 1911), pp. 607–14. Figs 7.

The experiments were planned to test the validity of the assumption that certain schists and contact metamorphic rocks have developed through the recrystallization of solid phases of previously existing rocks. A hand specimen of dunite and another of pyroxenite were subjected to a temperature of from 1,200 to 1,300° for nine months without showing signs of melting. The observed changes were textural, mineralogical, and chemical. The pyroxenite became a porous, coarse-grained aggregate of yellow, monoclinic pyroxenes spotted with ferric oxide grains. The olivine of the original rock had completely disappeared. The dunite was changed from an aggregate of angular and rounded colorless olivine grains interspersed with bunches of serpentine to a rock in which no serpentine was visible, but in its place were groupings of colorless